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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
09/833,372	04/12/2001	Michael Wojtowicz	12-1100	3137

27160 7590 07/07/2006

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ART UNIT	**PAPER NUMBER**
2815	

DATE MAILED: 07/07/2006

Please find below and/or attached an Office communication concerning this application or proceeding.

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BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

Application Number: 09/833,372
Filing Date: April 12, 2001
Appellant(s): WOJTOWICZ, MICHAEL

John S. Paniaguas
For Appellant

EXAMINER'S ANSWER

This is in response to the appeal brief filed 3/3/06 appealing from the Office action mailed 11/9/04.

(1) Real Party in Interest

A statement identifying by name the real party in interest is contained in the brief.

(2) Related Appeals and Interferences

The examiner is not aware of any related appeals, interferences, or judicial proceedings which will directly affect or be directly affected by or have a bearing on the Board's decision in the pending appeal.

(3) Status of Claims

The statement of the status of claims contained in the brief is substantially correct. However, the rejection of claims 1, 8 and 9 under 35 USC 103 over Song in view of JP '164 or JP '934 has been removed.

(4) Status of Amendments After Final

The appellant's statement of the status of amendments after final rejection contained in the brief is correct.

(5) Summary of Claimed Subject Matter

The summary of claimed subject matter contained in the brief is substantially correct. Appellant describes a base layer "formed with a non-constant bandgap energy with a relatively low value at the collector base interface 30 and a higher value at the emitter base interface 32 in order to create an electrostatic field in the base to increase the carrier velocity and decrease the transit time of the device...The configuration of the device increases the injected electron transit time and at the same time increases the p-type carrier concentration to improve the operation efficiency of the device."

Please Note: Appellant has not alleged any special or unexpected phenomenon is produced by the use of a group III-V semiconductor system that is specifically a GaN based system.

(6) Grounds of Rejection to be Reviewed on Appeal

The appellant's statement of the grounds of rejection to be reviewed on appeal is substantially correct. However, as stated above, the rejection of claims 1, 8 and 9 under 35 USC 103 over Song in view of Jp '164 or Jp '934 has been removed.

(7) Claims Appendix

The copy of the appealed claims contained in the Appendix to the brief is correct.

(8) Evidence Relied Upon

6,410,944	Song	6-2002
5,831,277	Razeghi	11-1998
4,620,206	Ohta et al	10-1986
4-251,934	Kodama et al	9-1992
63-248,164	Kusano et al	10-1998

(9) Grounds of Rejection

The following ground(s) of rejection are applicable to the appealed claims:

Claims 1, 5, 8 and 9 are rejected under 35 U.S.C. 1O3(a) as being unpatentable over Song '944 in view of either one of JP 4-251934 (cited previously, English translation enclosed) or alternatively JP 63-248164 (previously made of record, English translation enclosed) and further in view of Razeghi '277.

a. Song generally discloses a III-V GaN-based HBT (see FIG 3): on a substrate 5 is formed an n+ GaN subcollector 3; an n- GaN collector; a p+ GaN base; a relatively wider bandgap n AlGaN emitter; and contacts formed on the subcollector, base and emitter, respectively. The claims are not anticipated because Song does not disclose an AlGaN/GaN superlattice employed for the base.

b. JP '934, see e.g., FIG. 1B, teaches an InP/InGaAs HBT which includes a wide-bandgap InP emitter; a more narrow-bandgap InGaAs collector; and a base composed of a CHIRPed Inp/InGaAs superlattice (the same materials employed for that HBT'S emitter and collector, respectively) with an effective bandgap that decreases from the emitter side to the collector side for the purpose of increasing the carrier drift, and therefore decreasing the transfer time, within the base region, thereby increasing the HBT'S speed (see e.g., paragraph [0005]).

c. JP '164 teaches an AlGaAs/GaAs HBT which includes a wide-bandgap AlGaAs emitter; a more narrow-bandgap GaAs collector; and a base composed of a CHIRPed (Al)GaAs superlattice (the same materials employed for that HBT's emitter and collector, respectively) with an effective bandgap that decreases from the emitter side to the collector side for the purpose of increasing the carrier drift, and therefore decreasing the transfer time, within the base region, thereby increasing the HBT's speed (e.g., English Abstract). Jp '164 also teaches CHIRP structure is advantageous for other III-V materials (GaN "and the like") and gives a partial list of other III-V materials on page 13. Semiconductor III-V materials in general have similar properties and typically make

analogous transistors. Substitution of one III-V material for another is generally considered obvious in the art absent any unexpected results.

d. It would have been obvious to one of ordinary skill in the art at the time of the invention to have employed within Song's (Al)GaN HBT, a CHIRPed superlattice base formed of the same materials employed for that HBT'S emitter and collector (i.e., AlGaN and GaN), respectively, as taught by either one of JP '934 or JP '164 for the purpose of producing an electric field that increases the carrier drift, and therefore decreases the carrier transfer time across the base, thereby increasing the speed of Song's AlGaN HBT.

e. It would have been further obvious to the skilled artisan to have specifically employed AlGaN and GaN in such a base superlattice because: (1) JP '934 and JP '164 each teaches that the base superlattice may be composed of the two particular materials that are employed for the emitter and the collector; (2) Song discloses that AlGaN and GaN, in particular, may be employed for the emitter and collector, respectively; (3) using these specific materials in the superlattice would enable good lattice matching between the emitter, base and collector as AlGaN and GaN are closely lattice matched; and (4) JP '164 teaches CHIRP structure is advantageous for other III-V system materials in general (GaN "and the like").

f. As explained above, JP '934 and JP '164 each provide motivation for **why** one would have wanted to employ an AlGaN/GaN superlattice in the base region of Song's AlGaN HBT. Assuming *arguendo* that Song, JP '934 and JP '164 must be read so narrowly as not sufficiently teaching that one actually **could** form a p+doped superlattice

of AlGaN/GaN, Razeghi provides further evidence that it was known at the time of the invention by those skilled in the art how to form a p+ AlGaN/GaN superlattice. Thus, it would have been further obvious to form a base superlattice from the specific materials of AlGaN/GaN because these are the materials specifically employed in the various regions of Song, and Razeghi teaches how to form a superlattice using these materials. Claim 1 is therefore obvious.

g. Regarding claim 5, Song does not disclose what particular materials may be used for the substrate on which the GaN-based HBT is grown. Razeghi teaches that sapphire or SiC are typically employed as a substrate for GaN-based devices thereover (col. 3). It would have been obvious to one of ordinary skill in the art at the time of the invention to have employed sapphire or SiC for the substrate as taught by Razeghi because these are the two primary substrate materials are used for GaN-based devices due to lattice-matching compatibility.

Claims 2-4, 10 and 11 are rejected under 35 U.S.C. 103(a) as being unpatentable over the prior art as applied to the claims above, and further in view of Ohta et al. '206.

a. The claims mentioned in the previous paragraphs recite a superlattice (i.e., a structure having alternating well and barrier material), but do not further require that the AlGaN barriers be graded across the superlattice (i.e., do not require the barrier Al content to decrease from the emitter towards the collector). As such, the claims previously mentioned read on either Song/JP '934/Razeghi or alternatively Song/JP

'164/Razeghi as explained above because the two Japanese references each teach at least that the CHIRP-graded superlattices may be formed specifically by varying the respective thicknesses of the barriers and wells (i.e., wherein the respective barrier and well compositions remain unchanged, but their successive, respective thicknesses are altered).

b. Claims 2-4, 10 and 11 set forth the further limitation that the CHIRPed base have graded-composition barriers. Regardless of whether either of JP '934 or JP '164 additionally teach the alternative use of CHIRPed superlattices that are specifically barrier-composition-graded instead of thickness-graded to produce the effective change in the base's bandgap, Ohta teaches that either barrier-thickness-grading or barrier-composition-grading can be employed in CHIRPed superlattices to produce effective band-gap changes in superlattice structures (see e.g., F1Gs 14-21). Thus, it would have been obvious to one of ordinary skill in the art at the time of the invention to have employed barrier-graded CHIRPing as taught by Ohta instead of the thickness-graded CHIRPing in the CHIRPed superlattice HBT taught by Song/JP '934/Razeghi, or alternatively Song/JP '164/Razeghi, because the two CHIRP-grading schemes were conventionally known functional equivalent schemes, and because barrier-grading enables the use of constant thickness (i.e. thinner) barrier and well layers, and does not require taking into account the change of each barriers' and wells' respective thicknesses for design calculations.

(10) Response to Argument

The following **undisputed** facts are initially recited to clarify the record.

The present claims are directed towards a GaN-based heterojunction bipolar transistor with a CHIRP-graded base region.

A bipolar transistor is a three-terminal semiconductor device having abutting "emitter," "base" and "collector" regions respectively doped with either p or n impurities to form either an n-p-n or a p-n-p semiconductor structure having two back-to-back pn junctions. A "heterojunction" bipolar transistor (or HBT) is a bipolar transistor wherein at least one of the emitter-base junction and base collector junction is formed by abutting layers of different composition (such as GaAs and AlGaAs).

HBTs layers are commonly composed of materials from group IV of the periodic table (e.g., Si or SiGe alloys) or alternatively from materials taken from groups III and V of the periodic table. The most commonly used group III elements are Al, Ga and In; the most commonly used group V elements are N, P and As. Various species or particular alloy compositions of such "III-V" HBTs are commonly referenced in shorthand based upon the particular group V material that is present. For example, HBTs composed of GaAs and alloys of AlGaAs are commonly referenced as "Group III-As," or "III-As-based," "GaAs-based" or "As-based" HBTs.

Which particular Group III and V elements are present in a given III-V material dictate both the semiconductor layer's bandgap (the gap between the conduction band and valence band energy levels), lattice constant (the spacing between adjacent atoms), and crystalline structure (hexagonal or "wurtzite" structure for GaN-based systems and cubic structure for As-based and P-based systems). The bandgaps, lattice constants and crystalline structures for virtually all of the III-As, III-P and III-N systems have been well know for decades. For example, the substitution of a same-group element higher on the periodic table (e.g., the substitution of Al for Ga, both group III elements) increases the bandgap of the semiconductor layer, and simultaneously varies the lattice constant from a negligible to a significant degree. Bandgap Engineering is the discipline that studies how to manipulate semiconductor compositions so as to manipulate the resultant bandgaps and other well-known physical properties of the semiconductor crystal.

"Compositional grading" is the act of changing a semiconductor layer's composition in a given thickness direction so as to change the effective band gap in that direction. Sometimes this is performed by continuously changing the ratio of the group III elements: e.g., grading from GaAs to an alloy of AlxGa1-xAs, or more simply, "AlGaAs." Other times, due to strain issues resulting from lattice constant differences, effective graded bandgaps can be produced, based upon well-understood quantum physics principles, by growing a series of thin semiconductor layers with different bandgaps (called superlattices), and over the course of the growth, varying the

compositions/bandgaps and/or thicknesses of the individual layers. These special structures are called "graded superlattices" or "CHIRPed superlattices" (for **C**oherent **H**etero-Interface for carrier **R**eflection and **P**enetration).

The act of grading the base region of an HBT so that the bandgap decreased towards the collector was known. See JP '934 and JP '164 wherein this grading was performed to increase the drift velocity and transit time of the electrons through the base, and thereby improve device performance--exactly the same reason given by appellant. JP '934 and JP '164 also evidence that it was known to specifically employ superlattice CHIRPing or grading to produce the graded base region in the HBT.

Song '944 teaches that it was generally known how to make HBTs from GaN systems. And Razeghi teaches that it was actually known **how** to make superlattices from AlGaN systems.

Again, none of the foregoing facts are in dispute. The only dispute of the present appeal is whether, in light of all of these background facts, it would have been obvious at the time of the invention to have made a conventional CHIRP-graded base HBT specifically from a GaN-based material system.

In order for the Board to better understand the issue, the following is an explanation of what the present dispute is really about. Historically, different

semiconductor material systems matured to commercial viability at different times and at different rates. By the early 1990s, the SiGe-based, GaAs-based, and GaP-based material systems were pretty well established. There was a long-standing problem with the development of the GaN material system though. While it was known how to make undoped GaN-based layers (u-GaN or i-GaN) and GaN-based layers that were doped with n-type impurities (n-GaN), it was not until the mid 1990s that Shuji Nakamura and a few other inventors figured out how to produce p-doped GaN materials. As such, one of ordinary skill in the art of bandgap engineering either knew or could have reasonably predicted what general effects would result from changing the specific material systems used to make given semiconductor devices (including the prior art's CHIRP-graded HBTs). But no one knew how to make these conventional devices from GaN-based materials because no one knew how to make p-doped GaN. Once that enablement obstacle was overcome in the mid 1990s, making all conventional devices specifically from GaN-based systems generally became obvious. The fact that the present appellant's GaN HBT produces the same physics phenomenon as did the prior art HBTs of the other material systems evidences that no unexpected results occur when this particular material system is employed.

In regard to section I pages 3-8 of the arguments, appellant is primarily attacking each reference individually rather than together. On page 5 of the arguments appellant argues that Song does not teach a superlattice GaN/AlGaN base layer. In response, singling out individual references is not persuasive. The other applied references with

Song teach and suggest a GaN/AlGaN base as shown in the rejection above. Also on page 5 and 6, regarding the two layer emitter arguments, the claims do not structurally distinguish over the two layer emitter of Song where one layer is an AlGaN layer as claimed. The two layer emitter of Song shows the one emitter layer claimed.

On page 6 regarding "totally different" material arguments, such language is basically undefined and therefore basically meaningless here. Contrary to the "totally different" arguments, all materials are III-V materials and are considered in the art to be equivalent or least analogous for the most relevant semiconductor properties such as "direct bandgap", "crystal structure", "high mobility", etc. and as evidenced by JP'164 reciting on page 13 of the translation "if other hetero-junction system is used this invention will be effective. For instance they are InGaAs/InAlAs, InP/InGaAsP...and the like".

On page 7, second paragraph, appellant singles out JP'934 and states the base and other layers are not exactly the same as appellant. Again, singling out JP'934 alone is unpersuasive. See the rejection above for the teachings of '934 in view of the totality of applied references. Appellant's statement on page 6 regarding the same material superlattice base is correct. The claimed device is obvious. Appellant was not the first to invent a generic superlattice base transistor. Appellant was not the first to invent a generic GaN transistor. A patent for making an old device with old material should not be granted here. There are no unexpected results. Appellant argues on page 7, ("First, this logic omits the fact that the base layer disclosed in the JP '934 reference also includes the layer 13z, an InP layer. The examiner has not shown where the reference

teaches the use of the superlattice without the InP layer"), that Jp '934 shows a "base" with N-InP material. This characterization is incorrect as the certified translation shows regions 13a and 13b as "collector regions" rather than as "base"(14) region, as also would be perfectly clear to one of ordinary skill as layers 13a and 13b are doped n-type. The figure has a typo error. Thus appellant's arguments are wrong and irrelevant.

Appellant also argues on page 7, ("Second, the Examiner simply assumes…different material systems are interchangeable"), that it is well known in the art that the properties of one material system are not transferable to other material systems. This argument is not persuasive as it is contrarily well known in the art that the properties of materials in one material system such as group IV materials silicon and germanium are similar in lattice structure, dopant materials, mobility, indirect bandgap, etc., and materials in the III-V system InP, GaAs, GaN, AlGaN, InGaAlP, etc. are likewise similar in properties such as "lattice structure", "direct bandgap", "high mobility", dopant materials, etc. This is why JP '164 on page 13 of the translation states that the CHIRP superlattice can be **made with or applied to other III-V materials**. Appellant states that material properties are not "transferable" because no material is exactly the same as another material. However, these systems of materials clearly have well known similar properties and what is generally expected of one material in a particular system is generally expected of another material in the same system. This is fundamentally known in the art. Accordingly group IV elements are expected to function similar to other group IV elements and Group III-V materials are expected to function similar to other group III-V materials. So yes, in general, contrary to appellant's arguments, the

teachings and suggestions in a particular III-V material system is generally transferable to other III-V material systems. There are no unexpected results here. Accordingly arguments on page 8 directed to JP'164 materials are also unpersuasive. This is evidenced by the fact that all of the prior art references applied use the III-V material systems.

Argument on pages 8 and 9 regarding "interfaces" is also unpersuasive as Song shows a AlGaN emitter layer making an interface with a base region which from the suggestions of the applied art is a superlattice GaN/AlGaN material base region. Likewise as stated in the above rejection, the suggested base/collector interface includes a GaN collector making interface with the superlattice base region. Accordingly, applicant's argument ("None of the references cited disclose the AlGaN/GaN superlattice base and the cited interfaces") is unpersuasive. If any reference had, the claims would have been alternatively rejected under 35 USC 102 as anticipated.

Appellant's arguments set forth in section II (page 9) and section III (page 12) are based upon "the same reasons set forth in [section I] above" (page 10 line 3). No further arguments are made, and so the patentability of claims 2-5, 10 and 11 stand or fall with the other claims.

(11) Related Proceeding(s) Appendix

No decision rendered by a court or the Board is identified by the examiner in the Related Appeals and Interferences section of this examiner's answer.

For the above reasons, it is believed that the rejections should be sustained.

Respectfully submitted,

Jerome Jackson

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PRIMARY EXAMINER

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